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(54) Title: POLYMERIZATION PROCESS AND CATALYST

## (57) Abstract

A process and a catalyst for the production of elastomeric, primarily stereoregular poly- $\alpha$ -olefin characterized by a relatively narrow distribution of relatively short block lengths, which comprise the polymerization of  $\alpha$ -olefin of at least 3 carbon atoms in the presence of a catalyst which comprises the reaction product of a magnesium oxy compound and a tetravalent titanium halide in the presence of an electron donor, an organoaluminum compound and a selectivity control agent which is an aromatic heterocyclic nitrogen compound.

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POLYMERIZATION PROCESS AND CATALYSTField of the Invention

This invention relates to the production of elastomeric, primarily stereoregular polyolefins, to a process of producing such polymers and to a catalyst useful in such a process.

Background of the Invention

Several U.S. patents, to Natta, e.g., U.S. 3,112,300 and U.S. 3,112,301, describe steric structural types for polypropylene and other poly- $\alpha$ -olefins wherein the  $\alpha$ -olefin has 3 or more carbon atoms. Using polypropylene as an example, a polypropylene is termed "isotactic" if the methyl groups are all aligned on the same side of the straight polymer chain. If the methyl groups alternate from one side of the chain to the other, the polymer is termed "syndiotactic." These two forms containing a regular steric arrangement of methyl groups, taken together, are generically termed "stereoregular." In contrast, a polypropylene in which the methyl groups are randomly arranged on both sides of the polymer chain is termed "atactic" or "stereo-irregular."

The two more conventionally encountered physical forms of polyolefin polymers such as polypropylene are crystalline and amorphous, which terms refer to the crystalline character, or lack thereof, of the polymer. It is known, for example, that crystalline polypropylene is of either the isotactic or syndiotactic structure and amorphous polypropylene is generally of the atactic structure. Polyolefins

such as polypropylene which have elastomeric properties are somewhat different. U.S. Patent 4,3353,225 discloses a fractionable elastomeric polypropylene which is said to have an isotactic content of 55% or less and also contain some syndiotactic and also some atactic structure. This patent and other patents directed to the catalyst used to produce the elastomeric polymer contain considerable information on the nature of the elastic-type polyolefins. A number of earlier U.S. patents, e.g., U.S. 3,175,999, U.S. 3,257,370 and U.S. 3,258,455, had disclosed polypropylene having elastomeric properties. Another earlier U.S. patent, U.S. 3,278,512, had disclosed primarily isotactic polypropylene polymers having elastomeric properties. Syndiotactic polypropylene historically has involved a somewhat different method of production but such is known from U.S. 3,335,121 and U.S. 3,364,190, for example. A catalyst composition useful for the production of high molecular weight rubbery material from propylene is disclosed in U.S. 3,329,741.

Almost all of the polypropylene which is used commercially is crystalline isotactic polypropylene. Of lesser commercial importance is atactic polypropylene, in part because of its lack of strength. It would be of advantage to provide an improved process for the production of polyolefin polymers, wherein the olefin is an  $\alpha$ -olefin of at least 3 carbon atoms, which are elastomeric and primarily stereoregular.

#### Summary of the Invention

The present invention provides a process

for the production of elastomeric, primarily stereoregular polymers of  $\alpha$ -olefin of at least 3 carbon atoms and to the catalysts useful in the process. More particularly, the invention 5 provides a process for the production of such polymers which employs a catalyst formed from (1) a catalyst component derived from reaction of a magnesium oxy compound and a tetravalent titanium halide in the presence of an electron 10 donor, (2) an organoaluminum compound and (3) a selectivity control agent of specified type. In the process of the present invention, the choice of selectivity control agent will largely determine the degree of elastomeric character 15 and the nature of the stereoregularity exhibited by the elastomeric, primarily stereoregular polyolefin. The selectivity control agents useful in the present invention are aromatic, heterocyclic nitrogen compounds.

20. Description of the Invention

The polyolefin polymers of the invention are polymers of  $\alpha$ -olefins of at least 3 carbon atoms. The preferred class of  $\alpha$ -olefins comprises propylene and butylene and 25 particularly preferred is propylene. Largely for convenience, the invention will be illustrated in terms of propylene and polypropylene polymers although it should be understood that the invention is also applied to polymers of other  $\alpha$ -olefins of at least 3 carbon atoms. The "normal" well-known polypropylenes 30 are generally high molecular weight materials which consist of blocks of monomer units of relatively or extremely long average block 35 length ( $L$ ) and which are isotactic ( $<L\ iso>$ ),

for example having 50 to 200 monomer units. the prior art isotactic polymers which are prepared with a supported magnesium halide catalyst are of short isotactic block length, e.g., from 5 about 6 to about 15 monomeric units, but normally contain a wide distribution of polymer blocks of varying length. These prior art polymers are characterized by having relatively low tensile strength and by being tacky to the 10 touch.

The polyolefins of the present invention are characterized by having a narrow distribution of relatively short block lengths, by having relatively high tensile strength and 15 by being non-tacky to the touch. By "block lengths" is meant the number of recurring monomer units, for example, propylene units, which on the average occur before there is a defect in the polymer chain. By "defect" is 20 meant that the symmetry of the recurring units is ended and there are units of a different structure. By way of specific illustration, a block length of isotactic units is ended by the presence of a syndiotactic unit or units in the 25 polymeric chain. It is thought likely that the average block length, as determined by a numerical integration of the pentads which occur in the  $^{13}\text{C}$ -NMR spectrum, has a great effect on the properties of the polymer. For example, a 30 relatively short block length of from about 7 to about 15 monomer units tends to be found in a flexible or rubbery polymer which exhibits good elastomeric properties and is relatively strong with a tensile strength of from about 1500 psi 35 to about 3000 psi. Alternatively, block lengths

of greater than about 50 are characteristic of very stiff, highly crystalline isotactic polypropylene of the commercial type.

the process disclosed by the above U.S.

5 4,335,225 produces an elastomeric polypropylene having up to 55% and preferably less of isotactic polypropylene. The process requires a zirconium or hafnium catalyst supported on partially hydrated alumina. These catalysts 10 exhibit extremely low productivities, on the order of 1% to 2% of the productivity of the catalysts of the present process, and are not used commercially to any appreciable extent.

the polyolefins of the present invention 15 are produced in the presence of a catalyst derived from a procatalyst of a type which is well known. This procatalyst is the reaction product of a magnesium oxy compound of the formula  $MgR_1R_2$ , wherein  $R_1$  is alkoxy or aryloxy and  $R_2$  is alkyl, aryl, alkoxy, aryloxy or 20 halogen, preferably alkoxy, aryloxy or halogen, and a tetravalent titanium halide, which reaction takes place in the presence of an electron donor and, preferably, a halogenated 25 hydrocarbon. Such procatalysts, also termed solid catalyst components, are conventional and commercial. The olefin polymerization catalyst is formed from this procatalyst, an organoaluminum compound and an aromatic 30 heterocyclic nitrogen compound as selectivity control agent.

Examples of magnesium oxy compounds useful as precursors of the procatalyst are alkoxy or aryloxy magnesium halides such as 35 isobutoxymagnesium chloride, ethoxymagnesium

bromide, phenoxymagnesium iodide, cumyloxymagnesium bromide, naphthoxymagnesium chloride and  $Mg_4(OCH_3OH)_6(CH_3OH)_{10}Cl_2$ . Other magnesium diaryloxides such as magnesium di-

5 isopropoxide, magnesium diethoxide, magnesium dibutoxide, magnesium diphenoxide, magnesium dinaphthoxide and ethyoxymagnesium isobutoxide.

Magnesium compounds as disclosed in U.S.

4,710,482 are preferred, especially

10  $Mg_4(OCH_3)_6(CH_3OH)_{10}X_2$  wherein X is a resorcinol or substituted resorcinol monoanion. Also useful are magnesium compounds which have one alkyl or aryl group and one alkoxy or aryloxy group.

15 Examples of these compounds are phenylmagnesium phenoxide, ethylmagnesium butoxide, ethylmagnesium phenoxide and naphthylmagnesium isoamyloxide.

The reaction of the magnesium oxy compound and the tetravalent titanium halide,

20 conventionally termed a halogenation reaction, produces a magnesium halide in which the atomic ratio of halogen to magnesium is at least 1.2. Preferred reaction products are those in which the halogenation proceeds more completely, i.e.,

25 the reaction product has an atomic ratio of halogen to magnesium of at least 1.5. Except in those instances wherein the magnesium compound contains a phenoxide moiety, e.g., a resorcinol moiety, the most preferred reactions produce a

30 fully halogenated reaction product. The halogenation reactions suitably employ a molar ratio of magnesium compound to titanium compound of from 0.005:1 to 2:1, preferably from 0.01:1 to 1:1. The halogenation reaction, as stated,

35 takes place in the additional presence of an

electron donor and, optionally, a halohydrocarbon diluent.

Suitable tetravalent titanium halides are titanium tetrahalides or the corresponding compounds of one or two alkoxy or aryloxy substituents and three or two halide moieties, respectively. Illustrative of these latter titanium halides are dihexanoxytitanium dichloride, diethoxytitanium dibromide, isopropoxytitanium triiodide and phenoxytitanium trichloride. The titanium tetrahalides are particularly preferred, especially titanium tetrachloride.

The reaction of the magnesium compound and the tetravalent titanium compound is conducted in the presence of an electron donor. Suitable electron donors include ethers, esters, ketones, phenols, amines, amides, imines, nitriles, phosphines, silanes, phosphites, stibines, arsines, phosphoramides and alcoholates.

Examples of suitable electron donors are those disclosed in U.S. 4,442,276. The preferred electron donors are esters of aliphatic and aromatic carboxylic acids, particularly acids of two carboxyl groups. Illustrative esters include dimethyl carbonate, dimethyl adipate, dimethyl fumarate, dibutyl maleate, ethylisopropyl oxalate, diethyl phthalate and diisobutyl phthalate. The most preferred electron donors of the halogenation reaction are dialkyl phthalates.

Suitable halohydrocarbons useful as the optional component of the halogenation reaction include aliphatic halides and aromatic halides. Aliphatic monohalides such as butyl chloride and

amyl chloride are suitable but preferred aliphatic halides have from 1 to 12 carbon atoms per molecule, preferably from 1 to 9 carbon atoms per molecule, and at least two halogen atoms. Illustrative of such preferred aliphatic halohydrocarbons are dibromomethane, trichloromethane, 1,2-dichloroethane, dichlorobutane, 1,1,1-trichloroethane, trichlorocyclohexane, dichlorofluoroethane, trichloropropane, trichlorofluorooctane, dibromodifluorodecane, hexachloroethane, carbon tetrachloride and tetrachloroisooctane. The preferred aliphatic halohydrocarbons are carbon tetrachloride and 1,1,1-trichloroethane.

15 Suitable aromatic halohydrocarbons include chlorobenzene, bromobenzene, dichlorobenzene, dichlorodibromobenzene, chloronaphthalene, chlorotoluene and dichlorotoluene. The preferred aromatic halohydrocarbons are

20 chlorobenzene and dichlorobenzene, especially chlorobenzene.

The halogenation typically results in the production of a solid reaction product which, in one embodiment, is isolated from the product mixture by filtration, decantation or other conventional procedure. The product is suitably washed with inert hydrocarbon as described below to remove any unreacted, absorbed material. In a preferred embodiment, however, the initial reaction product is contacted with additional tetravalent titanium halide which is the same or is a different tetravalent titanium halide from that previously used. For this contacting also, the preferred tetravalent titanium halide is a titanium tetrahalide, particularly titanium

tetrachloride. This contacting serves to increase the halide content of the solid catalyst component. The halide content is preferably greater than 90% of the ionic equivalents of magnesium plus titanium in the solid catalyst component. This contacting is suitably conducted at a temperature of from 60°C to 136°C over a period of 0.1 hour to 6 hours in the option presence of an inert hydrocarbon diluent. The contacting, conducted with one or with several portions of tetravalent titanium halide, is preferably effected at a temperature of from 70°C to 120°C with a contact time of about 0.5 hour to about 3.5 hours. After the treatment with tetravalent titanium halide, the solid catalyst component, i.e., the procatalyst, is isolated from the media of its production by conventional methods and washed to remove unreacted titanium compounds. The titanium content of the final, washed, catalyst component is suitably up to about 4.5% by weight and preferably from 1.5 to 3.6% by weight. The product contains magnesium and titanium species, preferably present as predominantly the chlorides.

The material employed to wash to solid catalyst component is an inert, light hydrocarbon diluent. The hydrocarbon is aliphatic, alicyclic or aromatic but is preferably an aliphatic hydrocarbon such as isopentane, n-hexane and iso-octane. Isopentane is particularly preferred. The quantity of light hydrocarbon to be used is from 5 cc to 100 per gram of procatalyst in each of from 2 to 6 separate washes and preferably about 25 cc

hydrocarbon per gram of procatalyst in each wash. The resulting solid product is the procatalyst from which, together with the organoaluminum compound (cocatalyst) and 5 selectivity control agent, the polymerization catalyst is formed.

The organoaluminum compound cocatalyst is usefully any of the known aluminum-containing activators in olefin polymerization catalysts 10 which are based on a titanium halide including dialkylaluminum halides or alkylaluminum dihalides. Preferably, however, the organoaluminum compound is halide free and best results are obtained if at least the major 15 proportion of the organoaluminum compound is a trialkylaluminum wherein each of the alkyl groups has 1 to 6 carbon atoms. Trimethylaluminum, triethylaluminum, tri-n-propylaluminum, tri-i-propylaluminum, tri-i- 20 butylaluminum and dibutylamylaluminum are illustrative. The trialkylaluminum is, on occasion used in combination with an alkylaluminum halide, e.g., diethylaluminum 25 chloride, but preferably the sole organoaluminum compound is a trialkylaluminum.

The organoaluminum compound is used in combination with a selectivity control agent which is provided separately or in combination (complex) with the organoaluminum compound. The 30 selectivity control agent is employed in an amount of from 1 mol to 100 mols per mol of titanium compound of the procatalyst, preferably from 10 mols to 80 mols per mol of titanium compound. In the present invention, the 35 selectivity control agent is an aromatic

heterocyclic nitrogen compound, the choice of which will largely determine the degree of elasticity and the stereoregular character of the polyolefin product produced in the process which utilizes the olefin polymerization catalyst.

The aromatic heterocyclic nitrogen compounds which are employed in the process of the invention are those where at least one nitrogen is not unduly hindered by the presence of substituent groups on adjacent carbon atoms, e.g., the nitrogen is unhindered by the presence of substituent groups or adjacent carbon atoms or is "effectively" hindered by such groups. By the term "effective" hindrance is meant steric hindrance by substituent groups located on adjacent carbon atoms which are not so bulky as to prevent the formation of an elastomeric, primarily stereoregular polyolefin. Without wishing to be bound by any particular theory, it is considered likely that if the substituent groups are too bulky, the aromatic heterocyclic nitrogen compound will not be able to coordinate with other components of the catalyst system and will not provide stereochemical control.

In one embodiment of the invention the selectivity control agent is an unhindered aromatic heterocyclic nitrogen compound and the catalyst prepared therewith serves to produce elastomeric, primarily isotactic polymers according to the process of the invention. The aromatic heterocyclic nitrogen compound is effectively unhindered when at least one heterocyclic nitrogen atom is substituted on at least one adjacent carbon atom with a hydrogen.

Thus, the use of pyridine as a selectivity control agents produces the elastomeric, primarily isotactic polypropylene as does a substituted pyridine substituted by other than 5 hydrogen on one adjacent carbon atom, e.g., acridine. Alternatively, use of an acridine containing a methyl group substituent on the available carbon atom adjacent to the nitrogen does not result in the production of primarily 10 isotactic polymer. The presence of a bulky substituent on each adjacent carbon atom, e.g., 2,6-di-t-butylpyridine, does not result in production of primarily stereoregular product. Other unhindered aromatic heterocyclic nitrogen 15 compounds are pyrazine, 3,4,5-trichloropyrazine, 1,3,5-triazine, phenazine, 2,6-dimethylpyrazine, quinazoline, 2-picoline, quinoline, 2-methylpyrazine and 2,4-dichloropyrimidine.

In a second embodiment of the invention, 20 the selectivity control agent is a less effectively hindered aromatic heterocyclic nitrogen compound wherein at least one of the substituents on the adjacent carbon atoms of each nitrogen provide some degree of hindrance 25 but such hindrance is insufficient to prevent the production of elastomeric, primarily isotactic polymer. Such substituents are methoxy, chloro or a portion of a fused aromatic ring. Illustrative of such aromatic 30 heterocyclic nitrogen compounds are 2,6-dichloropyridine, 2-chloroquinoline, 2-chloro-6-methoxypyridine and 2,4,5,6-tetrachloropyrimidine.

In the third embodiment of the invention 35 the selectivity control agent is an effectively

hindered aromatic heterocyclic nitrogen compound wherein the steric hindrance arises from the presence of substituents on the carbon atoms adjacent to each nitrogen atom are hindered by groups other than chloro or methoxy or a fused aromatic ring. Use of a catalyst formed from, inter alia, such a selectivity control agent results in the formation of an elastomeric, primarily stereoregular polymer which in this embodiment is a syndiotactic polymer.

Illustrative of this class of aromatic heterocyclic nitrogen compounds are 2,6-lutidine, 2,4,6-collidine, 2,3-dimethylquinoxaline and tetramethylpyrazine.

To prepare the final polymerization catalyst, the procatalyst, cocatalyst and the selectivity control agent are simply combined, preferably employing the components in quantities sufficient to provide in the catalyst an atomic ratio of aluminum to titanium of from 1 to 150, particularly from about 10 to about 150, although higher ratios may be used. In general, an increase in the ratio of aluminum to titanium results in greater catalyst activity but leads to increased catalyst residues in the unextracted product. The atomic ratio will vary depending upon the process and product desired. Atomic ratios of aluminum to titanium from 30 to 100 are most advantageous, particularly ratios from 50 to 80.

Polymerization of the  $\alpha$ -olefins such as propylene according to the invention is conducted in a liquid system with a diluent such as a paraffinic liquid of 3 to 15 carbon atoms per molecule or in a liquid system containing

propylene as the diluent employed alone or in combination with a small amount of propane. Liquid-phase propylene polymerization is conducted at a temperature of 50°C to 80°C and a pressure sufficient to maintain liquid conditions. The process is suitably conducted batchwise but preferably is effected by a continuous reaction. In the latter system the liquid in the reaction zone is maintained at reaction conditions, monomer is continuously charged to the reaction zone, catalyst components are also charged continuously or at frequent intervals and reaction mixture containing polymer is withdrawn from the reaction zone continuously or at frequent intervals. Under these conditions, the polymer is produced as a slurry in the reaction mixture and is recovered by conventional methods and the reaction mixture is suitable for recycle. The catalyst of the invention is sufficiently active and specific in propylene polymerization so that removal of catalyst residues or atactic polymer from the polypropylene product is not required. The process and catalyst are particularly suited for operation in a continuous liquid phase reaction but alternatively are useful in a batchwise liquid phase process or in a vapor phase reaction.

It is well known that supported coordination procatalysts and catalyst systems of the type used in the present process are highly sensitive, in varying degrees, to catalyst poisons such as moisture, oxygen, oxides of carbon, polyolefins, acetylenic compounds and sulfur compounds. It should be

understood that in the practice of the invention both the physical equipment and the reactants and diluents are carefully dried and free of catalyst poisons.

5 The polymer products according to the process of the invention are elastomeric, primarily stereoregular poly- $\alpha$ -olefins derived from olefins of at least 3 carbon atoms. The polymers are characterized by the presence of a  
10 narrow distribution of relatively short block lengths and relatively high tensile strength. They are distinguished from other polyolefins by the combination of elastomeric properties and strength.

15 The invention is further illustrated by the following Examples which should not be regarded as limiting. In the examples, the productivity of the procatalyst is determined as kg polymer/g procatalyst in a standard one hour batch reaction. Catalyst activity is sometimes reported as kg polymer/g procatalyst hr or kg polymer/g Ti hr. The specificity towards the production of stereoregular polymers, either syndiotactic or isotactic, is determined by  
20 measurements involving the pentads observed in the  $^{13}\text{C}$ -NMR spectrum. See Randall, "Polymer Sequence Determination, Carbon-13 NMR Method," Academic Press, N.Y., 1977. A relationship has been determined to estimate the average block  
25 length by measuring the amount of xylene soluble polymer (SX) in accordance with regulations of the U.S. Food and Drug Administration. A XS test is conducted by dissolving a polymer sample in xylene in a stirred flask at 120°C. The flask  
30 is then immersed in a water bath at 25°C without  
35

stirring for 1 hour, during which the insoluble portion precipitates. The precipitate is removed by filtration and the solubles present in the filtrate are determined by evaporating a 5 20 ml aliquot of the filtrate, drying the residue under vacuum and weighing the residue. The xylene soluble content increases for short block length material and may include some amorphous or low molecular weight crystalline 10 material. See FDA regulations 121.2501 and 121.2510, 1970. The desirable numerical value for polypropylene polymers produced according to the invention is between about 35% and about 85%.

15 Preparation of Procatalysts

Procatalyst A: Magnesium methoxide solution (12%) was prepared by dissolving magnesium metal in methanol containing 0.125 equivalent of tetraethoxysilane (TEOS) and then filtering 20 through a medium porosity fritted glass filter to remove the slight amount of grey suspension.

The magnesium methoxide solution (791 g, 1.10 mol) was added slowly, at 60°C, to a solution of resorcinol (60.5 g, 0.55 mol) in 25 methanol (175 g) while stirring at 450 rpm with a 3-inch wide, curved teflon paddle of 1.5 in<sup>2</sup> surface area. By the time one-third of the methoxide had been added the flocculant precipitate had gotten quite viscous so another 30 155 g of methanol was added. After addition was complete the reaction was stirred for an hour then filtered. The solids were washed with methanol then isoctane then dried under moving nitrogen to yield crystalline cylindrical rods 35 of formula:  $Mg_4(OCH_3)_6(CH_3OH)_{10}(\text{resorcinolate})_2$ .

Partial desolvation of this precursor was carried out by boiling 40 g of solids in 300 g of cyclohexane, containing 120 g of tetraethoxysilane, until the volume had decreased by 20-30%.

The procatalyst was prepared by stirring 7.8 g of the partially desolvated precursor in 200 ml of a 50/50 (vol/vol) mixture of  $TiCl_4$ /chlorobenzene. After adding 5 isobutylphthalate (2.5 ml, 8.7 mmol) the mixture was heated in an oil bath and stirred at 115°C for 60 minutes. The mixture was filtered hot and the solids slurried in 200 ml of fresh  $TiCl_4$ /chlorobenzene mixture. Phthaloyl chloride (0.5 ml, 3.4 mmol) and p-toluoyl chloride (0.5 ml, 3.7 mmol) were added and the mixture stirred at 115°C. After 60 minutes the mixture was filtered hot and the solids slurried again into 10 200 ml of fresh  $TiCl_4$ /chlorobenzene mixture, heated at 115°C for 30 minutes and filtered hot. The solids were then slurried into 200 ml of fresh  $TiCl_4$ /chlorobenzene mixture, heated at 115°C for 30 minutes and filtered hot. The solids were then 15 slurried into 100 ml of fresh  $TiCl_4$ /chlorobenzene mixture, heated at 115°C for 10 minutes and filtered hot. The solids were allowed to cool 20 then washed with six 150 ml portions of isopentane and dried for 100 minutes under 25 moving nitrogen at 40°C. Ti=2.54%.

Procatalyst B: Magnesium ethoxide (8.2 g, 72 mmol) was slurried in 200 ml of 50/50 (vol/vol)  $TiCl_4$ /chlorobenzene and then isobutyl phthalate (2.5 ml, 8.5 mmol) was added at room 30 temperature. The gently stirring mixture was

heated to 110°C and held for 1 hour. The mixture was filtered hot and then another 200 ml of the  $TiCl_4$ /chlorobenzene mixture was added along with phthaloyl chloride (0.42 ml, 2.9 mmol) and ethyl benzoate (0.37 ml, 2.6 mmol) and the gently stirring slurry was held at 110°C for another 1.0 hour and filtered hot. The solids were slurried in one final 200 ml portion of the  $TiCl_4$ /chlorobenzene solvent mix and stirred gently for 0.5 hour at 110°C. The mixture was filtered hot and then allowed to cool to 40°C before washing with six 150 ml aliquots of isopentane. The resulting powder was dried for 100 minutes under moving nitrogen at 40°C. The yield is 9 gm of procatalyst.  $Ti=2.70\%$ .

Procatalyst C: Magnesium (104 g, 4.28 mol) was added portionwise to a mixture of 1.2 liters of methanol and 130 ml TEOS in a 3-liter-3-neck flask. Overnight stirring yielded a crystalline slush from which no solvent could be decanted. 1500 ml of TEOS was added as the slush was gently broken up with a spatula to produce a thick milky slurry which turned cold while stirring and turned white and thickened over an hour of stirring. The extremely thick slurry was diluted in two steps: 66% was diluted with 700 ml TEOS and 33% of that was diluted to 21 with TEOS to provide a milky slurry containing the equivalent of 22 g magnesium.

This slurry was heated gradually to a pot temperature of 153°C as distillate was collected over a 2 hour period. Microscopic examination revealed glassy granular particles in a narrow size distribution around 15 micron.

The granular particles (8.2 g, 56 mmol) were slurried in 200 ml of a 50/50 (vol/vol) mixture of  $TiCl_4$ /chlorobenzene. After adding isobutylphthalate (2.5 ml, 8.7 mmol) the mixture 5 was heated in an oil bath and stirred at 110°C for 60 minutes. The mixture was filtered hot and the solids slurried in 200 ml of fresh  $TiCl_4$ /chlorobenzene mixture. Phthaloyl chloride (0.42 ml, 2.9 mmol) and ethyl benzoate (0.37 ml, 10 2.6 mmol) were added and the mixture stirred at 110°C. After 60 minutes the mixture was filtered hot and the solids slurried again into 200 ml of fresh  $TiCl_4$ /chlorobenzene mixture. The slurry 15 was stirred for 30 minutes at 110°C then filtered hot. The solids were allowed to cool to 40°C and then washed with six 150 ml portions of isopentane and dried for 100 minutes under moving nitrogen at 40°C. The yield was 8.0 g of pink procatalyst. Analysis: 2.55% Ti.

20 Procatalyst D: Prepared from 330 lb of  $Mg(OEt)_2$  using the same procedure and molar ratios as described for procatalyst B. Ti=2.77%.

Examples 1-5

25 Procatalysts were used as a 5% slurry in mineral oil. Triethylaluminum (TEA) was used as a 0.28 M solution in isoctane, diethylaluminumchloride (DEAC) was used as a 1.54 M solution in heptane and tetramethylpyrazine was used as a 12% solution 30 in isoctane. Examples 1-4 illustrate the effect of using tetramethylpyrazine as selectivity control agent (SCA) with four procatalysts (A-D above). Example 5 is a comparative example in which the 35 tetramethylpyrazine had been omitted.

Triethylaluminum (1.2 mmol) and tetramethylpyrazine (0.24 mmol) were mixed together and then an amount of procatalyst slurry containing 0.012 mmol Ti was mixed with 5 that. After 20 minutes, 0.60 ml of DEAC was added to produce the total catalyst mixture. TEA (1.4 mmol) was then injected to 2.7 liters of propylene in a rapidly stirring 1 gallon stainless steel autoclave at 65°C followed by the 10 total catalyst mixture and polymerization was carried out for about 200 minutes at 65°C. After evaporation of excess propylene and cooling to room temperature the polymers were removed as a lump from the reactor then cut into pieces and 15 allowed to dry overnight in a fume hood prior to characterization.

The productivities, the xylene solubles content and the bulk polymer composition (as determined by NMR spectroscopy) for rubbery polymers of Examples 1-4 are listed in Table 1. 20 This polymer is primarily isotactic.

The pertinent properties for the polymers are shown in Table 2. Note that the tensile set values indicate that the primarily syndiotactic polymers of Examples 1, 3 and 4 are highly 25 elastic (Tset, after stretching to 300% length, of only 22-28%) whereas the primarily isotactic control case of example 5 is not as elastic (Tset of 120%).

TABLE 1  
Productivity and Composition of the Bulk Polypropylene  
From Various Phthalate Based Catalysts

5 Example	Catalyst No.	Xylene Sol. (% wt.)	Productivity (KG PP/g cat hr)	Syndiotactic (mol %)		Lsyn (ave)	Isotactic (mol %)	Liso (ave)	Defective (mol %)
				51	7				
1	A	79.0	8.5	51	7	24	9	26	26
2	B	63.8	4.8	52	7	22	8	26	26
3	C	80.8	7.1	49	6	25	9	26	26
10	D	56.6	8.4	49	7	26	10	25	25
5	*	41.7	3.5	20	7	64	19	16	16

\*Control, no SCA was used.

TABLE 2  
Properties of the Polymers from the Various Catalysts Examined

15 Example	Catalyst No.	Melt Flow (dg/min)	Tensile Set (20%)	Tensile Yield (psi)	Tensile Break (psi)	Elongation at Break (%)	
						1	2
1	A	2.08	28%	500	883	>917	
3	C	1.67	22%	441	836	>1000	
4	D	2.06	24%	499	875	>1000	
20	5	*	0.39	120%	1764	2837	770

\*Control, no SCA was used.

Examples 6-16 (SCA's producing primarily syndiotactic polymer)

The only cocatalyst used was triethylaluminum as a 0.28 molar solution in 5 isoctane. A 0.20 mmol sample of the 10 selectivity control agent, 0.01 mmol of the procatalyst and 0.7 mmol of the cocatalyst were mixed together and after 20 minutes were injected into 2700 ml of liquid propylene in a reactor where the polymerizations were carried out for 90 minutes at 60°C. Procatalyst A was 15 used throughout.

<sup>13</sup>C Magnetic Resonance

Spectra were obtained at 135°C on samples 15 dissolved in 1,2,4-trichlorobenzene. The spectrum reference was the methyl group assigned at 21.68 ppm. The calculated results of % syndiotactic, % isotactic, % defective and the respective average block lengths, for the 20 boiling isoctane fractionated polymer are shown in Tables 3 and 4.

Tensile Properties

In order to prepare samples for tensile measurements, about 60 g of the polymer was 25 blended in a Brabender mixer at 190°C with 0.3 g of IRGANOX®1010 antioxidant. After cooling, a 6" x 6" x 2mm plate was compression molded at 204°C under 5 tons pressure. Tensile bars were then cut from the plate using a 'C' die. The 30 measurement conditions are as described in ASTM D 412-83. Tensile set is the residual elongation imparted to a sample after stretching to an increase of 300% over its original length at a rate of 20 inches/minute and then allowing 35 it to recover to zero load at that same rate.

Tensile yield is the stress required to induce a permanent deformation in the sample. Tensile at break is the stress required to break the sample at an elongation rate of 20 inches/minute.

5 Elongation at break is the measured elongation at the break condition.

Melt flow index was determined under condition L (2160 g., 230°C) on a Tinius Olsen Plastometer. The strands, which were formed by extrusion through the 3mm die of the melt flow device, were stretched to an equilibrated length by hand pulling to nearly the break point several times. The diameter of the stretched strand is reported as the average of several measurements along the length of the strand.

10 The elasticity of the polymer is reported as the percentage elongation obtained upon applying a force nearly enough to break the strand (after which, of course, the strand returns to its 15 equilibrated length). This measurement is essentially equivalent to the reversible elastic elongation described by G. Natta et al in U.S. 20 3,175,999.

25 Table 5 shows the tensile properties for certain of the polymers produced.

TABLE 3  
(Less Hindered Heterocycles)

Example	SCA	% Syn	Lsyn	% iso	Liso	Lave	X.S. (%)	Stretch
30	5 None	22	6.7	60	14	12.0	42.4	20%
	6 2-picoline	19	6.3	62	14	12.2	49.4	9%
	7 Quinoline	21	6.7	61	15	12.9	44.4	14%
	8 2,3,5-trimethyl pyrazine	12	6.9	77	25	22.6	23.1	10%
35	9 Phenazine	21	7.0	62.5	17	14.5	36.4	14%
	10 Acridine	18	6.8	64	17	14.8	31.0	21%

TABLE 4  
(Hindered Heterocycles)

	Example	SCA	% Syn	Lsyn	% iso	Liso	Lave	X.S. (%)	Stretch
5	11	2,6-Lutidine	54.5	8.7	25	10	9.1	67.6	68%
	12	Quinaldine	52	8.9	27	12	10.0	62.4	110%
	13	2,3,5,6-Tetra-methylpyrazine	50	7.7	25	9	8.1	79.1	80%
10	14	2,4,6-Collidine	49	8.8	30	10	9.3	69.1	113%
	15	2,3-Dimethyl-quinoxaline	45	8.0	34	13	10.2	61.4	58%
	16	2,4-Dimethyl-quinoline	42	8.4	37	13	10.6	61.3	78%

15 TABLE 5  
Tensile Properties

	Example	Tset*	Tyield (psi)	Tbreak (psi)	Elongation @ break %
	6	Iso	171%	1289	2402
	10	Iso	204%	1529	2893
20	11	Syndio	65%	730	1554
	12	Syndio Compar	73%	822	1845
	13	Syndio Compar	52%	587	1114
	14	Syndio	110%	980	1651

\*Stretch to 400% of original length.

25 Examples 17-19

Using two different relatively less hindered heterocyclic selectivity control agent, which are the subject of this invention, and one effectively hindered heterocycle, 1.8 liters of 1-butene was polymerized under the same conditions used above for propylene polymerizations. The NMR results presented in Table 6 show that the less hindered SCAs (Example 14 and Example 15) produce predominantly isotactic polybutylene while the methyl hindered SCA (Example 16) produced primarily syndiotactactic polybutylene. The

tensile properties of these examples are shown in Table 7. As with the polypropylene case the polybutenes of the present invention exhibit higher tensile strength and higher tensile set values than the polymer of the more hindered nitrogen heterocycle (i.e., they are only mildly elastomeric).

TABLE 6  
Polybutylene

Example	SCA	% Iso	<u>&lt;Liso&gt;</u>	% Syn	<u>&lt;Lsyn&gt;</u>
17	2,3,5-trimethylpyrazine	51	12	19	5.9
18	Cyanuric chloride	68	18	12	5.6
19	2,6-lutidine	27	10	38	6.9

TABLE 7  
Polybutene Tensiles

Example	Tensile set	Tensile at break	Elongation at break
17	100%	.974 psi	590%
18	158%	2852 psi	480%
19	30%	>230 psi*	>1000%

20 \*Sample did not break at 1000% elongation.

## WHAT IS CLAIMED IS:

1. A process for the production of elastomeric, primarily stereoregular poly- $\alpha$ -olefin, wherein the  $\alpha$ -olefin is of at least 3 carbon atoms, characterized by short average block lengths which comprises polymerizing the  $\alpha$ -olefin in the presence of a catalyst which comprises:
  - 10 a) the reaction product of a magnesium oxy compound and a tetravalent titanium compound wherein the reaction takes place in the presence of an electron donor;
  - 15 b) an organoaluminum compound; and
  - c) a selectivity control agent which is an aromatic heterocyclic nitrogen compound which is not unduly hindered by the presence of substituents on carbon atoms adjacent to at least one nitrogen atom.
- 20 2. The process of claim 1 for the production of elastomeric, primarily syndiotactic polypropylene wherein each nitrogen of the aromatic heterocyclic nitrogen compound is effectively hindered.
- 25 3. The process of claim 2, wherein the nitrogen compound is selected from 2,3-dimethylquinoxaline, quinaldine, 2,6-lutidine, 2,4,6-collidine or tetramethylpyrazine.
- 30 4. The process of claim 3, wherein the tetravalent titanium halide is titanium tetrachloride.
- 35 5. The process of claim 4, wherein the magnesium compound is a compound of the formula  $MgR_1R_2$  wherein  $R_1$  is alkoxide or aryloxide and  $R_2$  is alkyl, aryl, alkoxide, aryloxide or halogen.
6. The process of claim 5, wherein  $R_1$  and

R<sub>2</sub> are ethoxide.

7. The process of claim 5, wherein the magnesium compound is of the formula Mg<sub>4</sub>(OCH<sub>3</sub>)<sub>6</sub>(CH<sub>3</sub>OH)<sub>10</sub>X<sub>2</sub> wherein X is a resorcinol or substituted resorcinol monoanion.

8. The process of claim 1 for the production of elastomeric, primarily isotactic poly- $\alpha$ -olefin wherein each nitrogen of the aromatic heterocyclic nitrogen compound is less hindered by the presence of chloro or methoxy groups on at least one adjacent carbon atom.

9. The process of claim 8, wherein the nitrogen compound is 2,6-dichloropyridine, 2-chloroquinoline, 2-chloro-6-methoxypyridine, 15 2,3-dichloroquinoxaline, 2,4,6-trichloropyrimidine or 2,4,5,6-tetrachloropyrimidine.

10. The process of claim 9, wherein the tetravalent titanium halide is titanium chloride.

11. The process of claim 10, wherein the magnesium compound is of the formula MgR<sub>1</sub>R<sub>2</sub> wherein R<sub>1</sub> is alkoxy or aryloxy and R<sub>2</sub> is alkoxy, aryloxy or halogen.

12. The process of claim 11, wherein R<sub>1</sub> and R<sub>2</sub> are ethoxide.

13. The process of claim 11, wherein the magnesium compound is of the formula Mg<sub>4</sub>(OCH<sub>3</sub>)<sub>6</sub>(CH<sub>3</sub>OH)<sub>10</sub>X<sub>2</sub> wherein X is a resorcinol or substituted resorcinol monoanion.

14. The process of claim 8, wherein the  $\alpha$ -olefin is propylene.

15. The process of claim 8, wherein the  $\alpha$ -olefin is 1-butene.

16. The process of claim 1 for the

production of elastomeric, primarily isotactic poly- $\alpha$ -olefin wherein at least one nitrogen of the aromatic heterocyclic nitrogen is unhindered.

5        17. The process of claim 16 wherein the nitrogen compound is pyrazine, 3,4,5-trichloropyridazine, 1,3,5-triazine, phenazine, pyridine, 2,6-dimethylpyrazine, quinazoline, 4,6-dichloropyrimidine, 2-picoline, 2,3,5-trimethylpyrazine, acridine, 2-methylpyrazine, 2,5-dimethylpyrazine, 2,3-dimethylpyrazine, 2,3-dichloroquinoxaline, quinoline, pyridazine or 2,4-dichloropyrimidine.

15        18. The process of claim 17, wherein the tetravalent titanium halide is titanium tetrachloride.

20        19. The process of claim 18, wherein the magnesium compound is of the formula  $MgR_1R_2$  wherein  $R_1$  is alkoxide or aryloxide and  $R_2$  is alkoxide, aryloxide or halogen.

25        20. The process of claim 19, wherein  $R_1$  and  $R_2$  are ethoxide.

21        21. The process of claim 19, wherein the magnesium compound is of the formula  $Mg_4(OCH_3)_6(CH_3OH)_{10}X_2$  wherein X is a resorcinol or substituted resorcinol monoanion.

22        22. The process of claim 16, wherein the  $\alpha$ -olefin is propylene.

30        23. The process of claim 16, wherein the  $\alpha$ -olefin is 1-butene.

24        24. A catalyst for use in the production of elastomeric, primarily stereoregular poly- $\alpha$ -olefin, wherein the  $\alpha$ -olefin has at least 3 carbon atoms, characterized by short average block lengths which comprises:

a) the reaction product of a magnesium oxy compound and a tetravalent titanium halide wherein the reaction takes place in the presence of an electron donor;

5 b) an organoaluminum compound; and

c) a selectivity control agent which is an aromatic heterocyclic nitrogen compound which is not unduly hindered by the presence of substituents on carbon atoms adjacent to at least one nitrogen atom.

10 25. The catalyst of claim 24, wherein the tetravalent titanium compound is titanium tetrachloride.

15 26. The catalyst of claim 25, wherein the magnesium oxy compound is of the formula  $MgR_1R_2$  wherein  $R_1$  is alkoxy or aryloxy and  $R_2$  alkoxy, aryloxy or halogen.

20 27. The catalyst of claim 26, wherein the nitrogen compound is 2,3-dimethylquinoxaline, quinaldine, 2,6-lutidine, 2,4,6-collidine or 2,4-dimethylquinoline.

25 28. The catalyst of claim 27, wherein  $R_1$  and  $R_2$  are ethoxy.

29. The catalyst of claim 27, wherein the magnesium oxy compound is of the formula  $Mg_4(OCH_3)_6(CH_3OH)_{10}X_2$  wherein  $X$  is a resorcinol or substituted resorcinol monoanion.

30 30. The catalyst of claim 26, wherein the nitrogen compound is 2,6-dichloropyridine, 2-chloroquinoline, 2-chloro-6-methoxypyridine, 2,3-dichloroquinoxaline, 2,4,6-trichloropyrimidine or 2,4,5,6-tetrachloropyrimidine.

35 31. The catalyst of claim 30, wherein  $R_1$  and  $R_2$  are ethoxy.

32. The catalyst of claim 30, wherein the magnesium oxy compound is of the formula  $Mg_4(OCH_3)_6(CH_3OH)_{10}X_2$  wherein X is a resorcinol or substituted resorcinol monoanion.

5 33. The catalyst of claim 26, wherein the nitrogen compound is pyrazine, 3,4,5-trichloropyridazine, phenazine, pyridine, 2,6-dimethylpyrazine, quinazoline, 2-methylpyrazine, 2,5-dimethylpyrazine, 1,3,5-triazine, 2,3,5-trimethylpyrazine, acridine, 2,3-dimethylpyrazine, 2,3-dichloroquinoxaline, quinoline, pyridazine or 2,4-dichloropyrimidine.

10 34. The catalyst of claim 33, wherein  $R_1$  and  $R_2$  are ethoxy.

15 35. The catalyst of claim 33, wherein the magnesium oxy compound is of the formula  $Mg_4(OCH_3)_6(CH_3OH)_{10}X_2$  wherein X is a resorcinol or substituted resorcinol monoanion.

# INTERNATIONAL SEARCH REPORT

International Application No. PCT/US90/02036

## I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all)

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC (5): C08F 4/654, 4/649, 10/06

U.S. CL. 526/124, 125, 141

## II. FIELDS SEARCHED

Classification System	Minimum Documentation Searched <sup>7</sup>	
		Classification Symbols
U.S.	502/123; 526/124, 125, 141	

Documentation Searched other than Minimum Documentation  
to the Extent that such Documents are Included in the Fields Searched<sup>8</sup>

## III. DOCUMENTS CONSIDERED TO BE RELEVANT<sup>9</sup>

Category <sup>10</sup>	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>
Y	US, A, 4,754,006 (MURATA ET AL) 28 JUNE 1988 See column 9, line 67 to column 10, line 13.	1-8, 14-29, 33-35
Y	US, A, 4,107,413 (GIANNINI ET AL) 15 AUGUST 1978. See column 3, lines 25-31 and Example 11.	1-8, 14-29, 33-35
Y	US, A, 4,393,182 (GOODALL ET AL) 12 JULY 1983. See column 2, line 54-62.	1-8, 14-29,
Y	US, A, 4,710,482 (JOB) 01 DECEMBER 1987 See column 3, lines 9-14.	7, 21, 29, 35
Y	US, A, 3,534,006 (KAMAISHI ET AL) 13 OCTOBER 1970. See column 3, lines 46-67.	3-7, 17-21, 27-29, 33-35
Y	US, A, 3,240,773 (BOOR) 15 MARCH 1966 See column 4, lines 3-14.	1-8, 14-29, 33-35

### \* Special categories of cited documents: <sup>14</sup>

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- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"A" document member of the same patent family

## IV. CERTIFICATION

Date of the Actual Completion of the International Search

Date of Mailing of this International Search Report

05 JULY 1990

09 AUG 1990

International Searching Authority

Signature of Authorized Officer

ISA/US

Edward J. Smith

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